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SESSION A
RESEARCH AND DEVELOPMENT OF MANUFACTURING SYSTEMS, TOOLS AND TECHNOLOGIES, NEW MATERIALS AND PRODUCTION DESIGN

MANUFACTURE OF TWO-LAYER CASTINGS WITH DIFFERENTIAL STRUCTURE AND PROPERTIES FROM CAST IRON BY INMOLD-PROCESS MODIFICATION

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Summary: *There has been described the original method of manufacture from one initial cast iron with the use of INMOLD-process modification of two-layer castings with a hard wear-resistant working layer from white iron and a tough plastic layer from high strength cast iron with globular graphite.*

Keywords: *castings with differential properties, INMOLD-process modification, white iron, high strength iron with globular graphite*

Raising of reliability and long service of equipment, machines and mechanisms, increasing of inter repairing terms of operation of continuously operated complexes, economizing of deficit structural materials can be provided by the use of two-layer and multi-layer cast iron parts with differential structure and properties of their separate parts.

The examples of such parts can be jaws of crushers, armor lined plates, slides of granular material bunkers, excavator teeth, knives of dredger rippers and other pieces of work operating in the conditions of unbumped abrasive and moderately bumped abrasive wear.

More often such parts should have hard wear resistant working surface and a soft impact resistant core, a matrix base or mounting components.

Wear resistance of the working surface of castings can be sufficiently provided by white iron with iron carbides (WI) and increased plasticity and ductility can be provided by magnesium high strength cast iron with globular graphite (HSIGG) of a ferrite class.

Present methods of production of cast bimetallic parts are more often used on melting in independent melting aggregates of heterogeneous alloys with their next simultaneous or stage-by-stage casting into a common mould or a mould [1,2]. The necessity of melting two heterogeneous alloys in different melting furnaces is an essential drawback of the mentioned methods in the production of bimetallic castings.

We developed and investigated a new method of manufacture of two-layer castings with hard wear-resistant working surface from white iron and soft anti-shock base from high strength iron with globular graphite; this method allows for removing the shown above main drawback of the existing ways of bimetallic castings manufacture [3,4].

The offered new method is based on the known method of INMOLD-process modification [5], according to which in the process of pouring the mould the initial liquid cast iron on the way of the melt movement is put through a special reaction chamber of a pouring gate system with a grain modificator. As a result of INMOLD-process due to the processes of INMOLD modification taking place the initial cast iron changes its properties; hence the structure and properties different from the structure and properties of the initial cast iron are formed [5].

For manufacture of two-layer castings with hard-working surface from white iron and soft anti-shock (impact) resistant base from high strength cast iron with globular graphite two technological variants were used:

- The first variant provided for pouring of a part of the working mould cavity with hypoeutectic cast iron inclined to crystallization with chilling (WI), with the subsequent adding of the same cast iron through the other (second) independent from the first pouring gate system, in the composition of which on the way of melt movement a reaction chamber with a spheroidizing modificator is put into operation (SM) (fig.1, a);

- The second variant provided for preliminary pouring of initial grey iron (GI) of eutectic or nearly eutectic composition into the cavity of the casting mould through the first pouring gate system with pouring of the melt through a reaction chamber of a pouring gate system with a carbide stabilizing modificator (SM) with a subsequent pouring of the rest, not filled on the first stage of the mould cavity with the same cast iron through the other independent from the first pouring gate system with a reaction chamber with a spheroidizing modificator (SM) (fig.1, b).

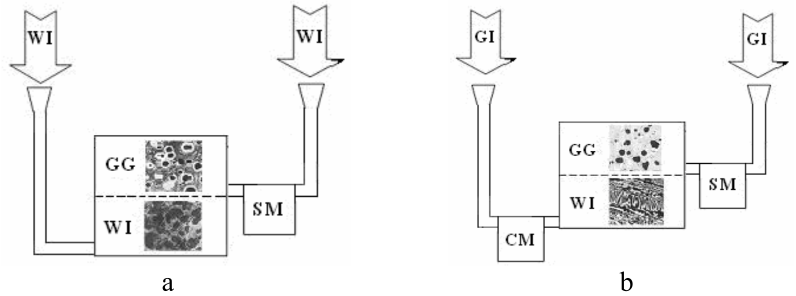


Figure 1.: Technological variants of two-layer castings manufacture

The object of the research was chosen a casting of the vertical plate type with dimensions 300x300x25 mm, mass $15 \pm 0{,}2$ kg, with two independent pouring gate systems (fig.2)

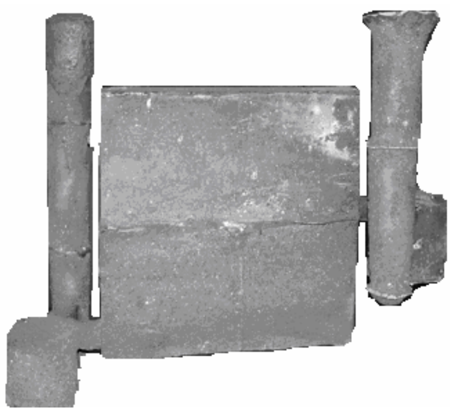


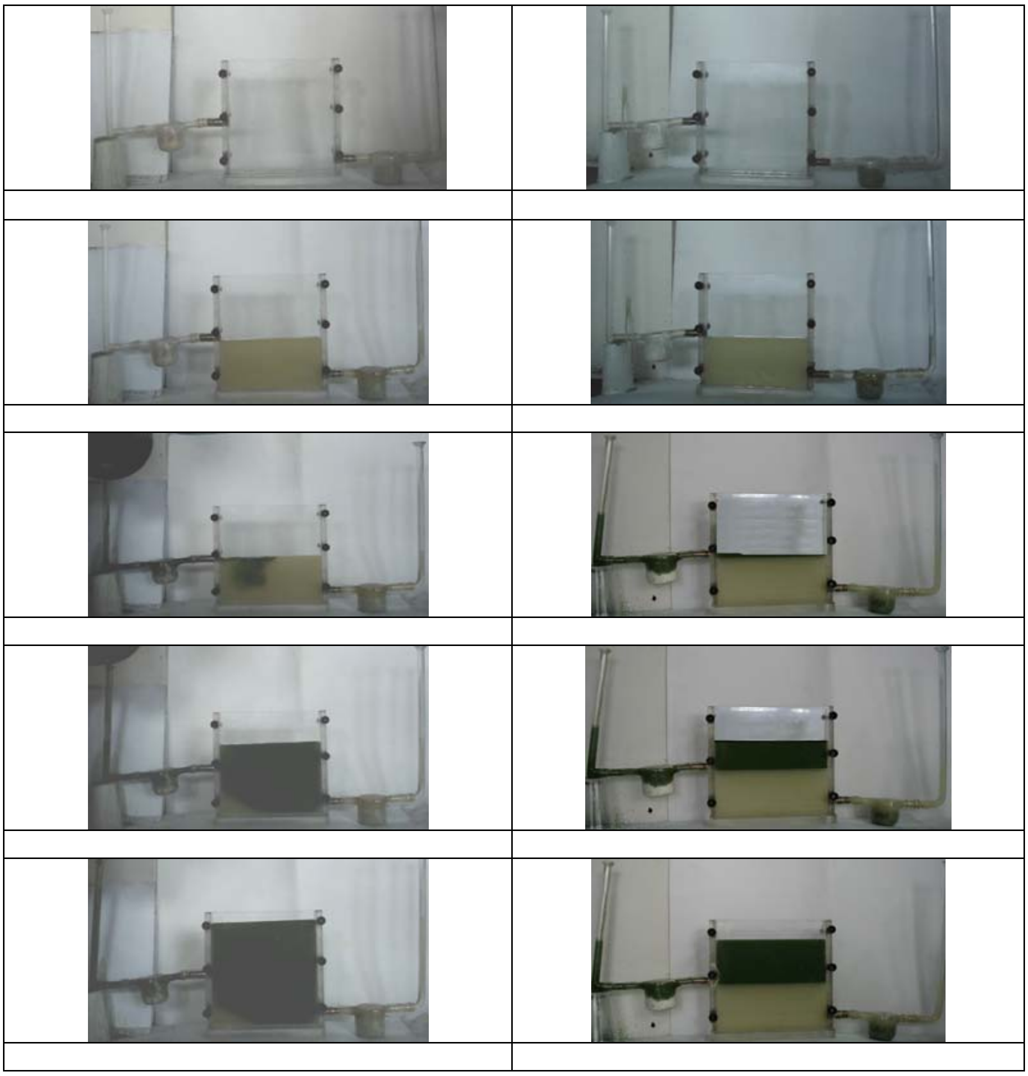
Figure 2.: The appearance of the experimental casting

The experimental two-layer (on height) castings were manufactured in dry sand-clay casting moulds by subsequent two-stage pouring through independent pouring gate systems of the initial liquid cast iron at temperature $1420 \pm 20°C$.

The initial cast iron was melted in the induction crucible electric furnace, model ИЧТ-006 with an acid lining on the charge consisting of pig iron and steel scrap (Steel 3). In the experiments the composition of the initial pre-eutectic cast iron, having a tendency to crystallization in the limits: 2,80...3,20%C; 0,55…0,60%Si; 0,20…0,25%Mn; 0,040…0,045%P%; 0,018…0,020%S, and the initial grey iron was – 3,20…3,40%C; 1,0…1,6%Si; 0,3…0,5%Mn; 0,040…0,045%P%; 0,018…0,020%S.

As a spheroidizing modificator put into a reaction chamber for INMOLD-process of the initial cast iron with the aim of obtaining the structure and properties of high strength cast iron with a globular graphite (HSIGG) a ferrosilicon-magnesium alloy of the grade ФСМг7 was used, and as a carbide stabilizing modificator for obtaining structure and properties of the white iron (WI) – nickel-manganese alloy of grade НМг15 [6] was used. The quantity of the modificator with the particle sizes 1,0…5,0 mm in all the experiments was 2% from the mass of the cast iron.

The results of the experiments were analyzed according to the character and the color of the fracture in the central section of the experimental castings.
Due to preliminary investigation of the process of the two-layer castings manufacture on a transparent physical model [7], where paraffin was used as a model substance, it was stated that in case of continuous pouring of the model composition melt through the two independent pouring gate systems (fig.3, a) and also with a little time delay between the two stages of pouring (fig.3, a), it is impossible to obtain the castings with a differential structure and properties of the metal in their upper and lower parts. The reason of this is an intensive mixing of a liquid phase (preliminary poured at the first stage through the first pouring gate system and being poured through the other pouring system), which leads to leveling of painting of the model liquid along the whole body of the casting (see fig.3, a).
Differentiation of the structure and properties in upper and lower layers of the casting while using INMOLD-process modification can be achieved at a certain time delay between the two stages of casting pouring with metal (see fig.3, b).



a b

Figure 3.: Obtaining of two-layer casting without a time delay (a) and with a time delay (b) between the two stages of melt pouring

For determining of optimal conditions for a two-layer casting formation in the conditions of the experiment the time interval between the two stages of pouring was discretely increased from 5 to 120 seconds.
The results of the experiments carried out on the sample castings showed that both in case of two-layer castings manufacture from white iron and in case of two-layer castings manufactured from the initial grey iron a qualitative compact(solid) fracture with a clear-cut border line between a wear resistant lower layer from white iron and the upper layer of the casting from high strength cast iron with globular graphite is provided by a time delay between the two stages of mold pouring at 60…90 seconds (fig.4, d, f).

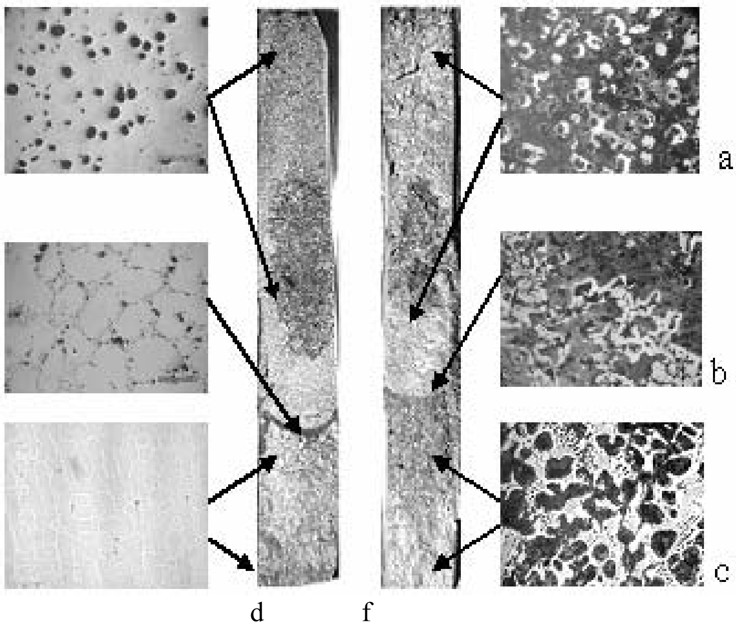


Figure 4.: Fracture and microstructure of the casting "Plate" with a time delay 60 (d) and 90 (f) seconds between the two stages of the melt pouring

A significant quantity of a ledeburite eutectic in the combination with disperse decompositional products of the primary austenite in a microstructure (fig.4, b) provided for hardness of a lower surface of the casting at the level 380…400 HB. The structure of the upper layer of the casting consisted in globular graphite of a regular form in perlite-ferrite metallic matrix (fig.4, a). Hardness of the upper surface of the casting was 220…240 HB. The quantity of the whitened working layer in the casting made at a time delay of 60 seconds between the stages of melt pouring was 50 mm (fig.4, d), and at a time delay of 90 seconds it was 80 mm (fig.4, f).
At a time delay between the two stages of pouring less then 50-60 seconds in the lower part of the casting a layer of white iron with insignificant thickness is formed (up to 10…20 mm)., and in the main volume the grey iron with plate graphite inclusions is formed (fig.5, a,b). Hardness of a lower part of the casting is 360…380 HB, in the upper part of the casting 140…180 HB.
In case of an extra time delay between the two stages of pouring (more than 90 seconds) the thickness of the white iron layer in the lower part of the pattern casting is increased up to 120 mm. Further at a definite height stretch a transition zone of grey iron is formed (fig.6, b), above which high strength cast iron with globular graphite is formed (fig.6, a). However, the quality of the obtained castings is decreasing, which, in our opinion, is explained in the following way.
Increasing of a time delay after pouring of the first portion above optimal leads to the formation of a rather thick and strong crum on the mirror of the poured portion. In pouring of the second portion the amount of the heat of the poured metal is not enough for melting of the formed solid crum, as a result after pouring completion the first (lower) and the other (upper) portions solidify irrespective of each ocher. As a result of solidifying of the first portion poured through the gate pouring system in a closed space in the conditions of melt supply shortage and as a result of impossibility of compensation of an alloy shrinkage in solidifying and cooling by the melt of the upper portion the shrink holes (shrinkage cavities) and pores are formed in the upper part of the lower portion in the zone of melting. Besides, the oxide films which appeared on the surface of the first layer are not dissolved after pouring of the second portion, which leads to their getting into the transition layer and is the reason of incomplete fusion (porosity) and non-metallic inclusions of the latter (fig.6).

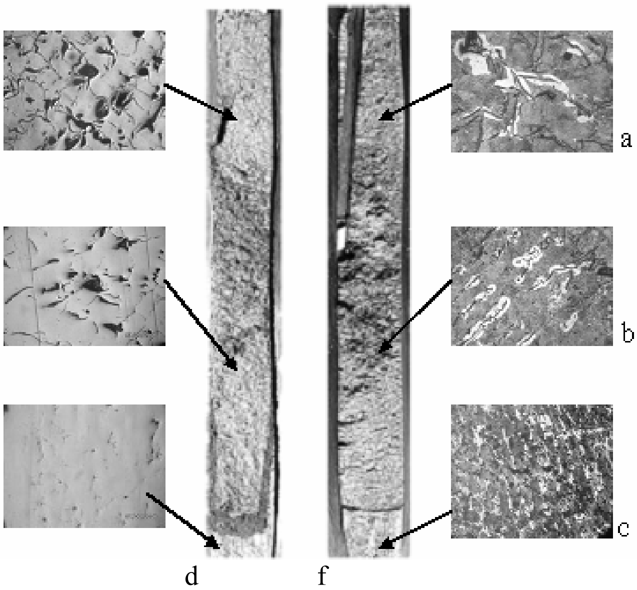


Figure 5.: Fracture and microstructure of the casting “Plate” with a time delay of 30 (d) and 45 (f) seconds between the two stages of melt pouring

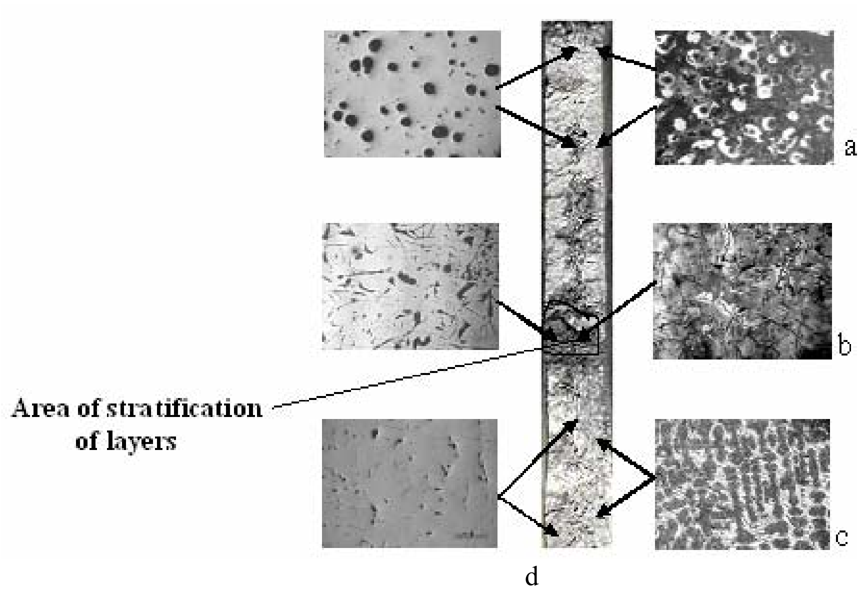


Figure 6.: Fracture and microstructure of the castings “Plate” with a time delay of 120 seconds between the pouring stages of the melt

To the advantages of the described method of two-layer castings manufacture we can refer the exclusion of the necessity of two furnaces for melting heterogeneous cast irons or the necessity in ladle modification of a part of the base metal of one melting. To this we should add all known advantages of the INMOLD-process modification of cast iron in comparison with the ladle ones: absence of labour expenditures on the modification operation, pyroeffect, smoke formation, demodification, etc.

CONCLUSIONS

1. The developed new technology and original technological variants with the use of the INMOLD-process modification allows for obtaining two layer castings with differential structure and properties from one initial base cast iron.
2. While manufacturing two layer castings of the vertical plate type with differential structure and properties from initial (white and grey) cast iron with the use of the INMOLD-process modification a certain time delay between the two stages of pouring the mould by the melt is necessary. A time delay less than optimal doesn’t provide obtaining of the lower layer of the white iron with the given thickness and makes it difficult to obtain high strength iron with globular graphite in the rest of the volume. The duration of a time delay more than optimal leads to the formation of defects in the zone of melting of two portions of the metal.
3. While manufacturing two layer castings of the vertical plate type with the mass up to 20 kg an optimal duration between the two stages of pouring of the initial cast iron is 60…90 seconds time delay: during such time delay there is formed a qualitative casting with differential structure and properties with the combination of a lower zone from white iron and upper zone from high strength cast iron with globular graphite in a perlite-ferrite metallic matrix.

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